NOTES ON THE TOPOGRAPHY AND GEOLOGY OF NEW MEXICO.

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ON the parallel of 37 degrees north, New Mexico is but fifty-four miles from southwest Kansas. The distance is measured by one degree of longitude between meridians 102 deg. and 103 deg. west. The geological formations bridging the interval are, no doubt, identical with those of western Kansas and eastern New Mexico. The Cimarron river, deriving its waters from the territorial slope of the Raton mountains, is the only river entering Kansas, except the Arkansas, having its sources in the Cordilleran region. The area of New Mexico is more than once and a half that of Kansas, and is about measured by that of Great Britain and Ireland. Its average altitude is at least 3000 feet above the average of Kansas, and its lowest parts are above the mean of Kansas.

The geology of New Mexico is less certainly known than that of any other political division of the geographically connected United States. The present paper will only call attention to certain picturesque features of topographic and geologic interest.

Unlike Kansas, the Paleozoic formations in the territory would be a matter of inference only, except for its mountains and the canyons, their derivatives, for those early deposits are deeply covered with Mesozoic and Cenozoic strata elsewhere than in the vicinity of these elevations and trenches. Fortunately, Kansas, without mountains within her boundaries to destroy the vastness of her agricultural capacities, revels in the successive disclosures of her strata, from early Carboniferous to late Alluvial, giving almost unexampled access to the geological benefactions of all time. This condition to human advantage, however, is to be credited to the slow uplifting agency of the Ozarkian region to the east and southeast of her present borders.

The territory is ridged and cross-ridged with mountain segments, which together constitute geographic ranges for hundreds of miles, but continuous sierras end in the middle of the north half, in the Sangre de Cristo range, apparently the oldest orographic monument. The range culminates in an altitude of over 13,000 feet, seventy-five miles south of the Colorado line and thirty miles east of the central meridian of the territory, the 106th. From this point it broadens and splits into three sharply crested, nearly parallel ranges, of which the eastern is longest, and which extends fifty-five miles further south.

These ranges average from 9000 to 11,000 feet in height, in order from east to west, the longest having least altitude and the shortest, or western, the greatest. The intervening troughs have few, if any, intrusives, and are occupied by tributaries of the Pecos river, deeply canyoned in their upper courses, and with narrow, fertile valleys near their points of issue. The ranges vary somewhat in the character of their granitic masses. The eastern is fine-grained, the middle syenitic, and the western with large crystals of red feldspar.

To indulge a somewhat grotesque but instructive imagination, one may picture a huge book, so bound that its pages lie flat when opened, with its back on the Kansas-Colorado line, its top to the south, and the right and left outer edges of its leaves resting on the Rocky Mountains and the Kansas-Missouri boundary. The outer edges on the left will be imbricated like the shingles on a roof; they will represent the Kansas stratigraphic exposition. Let the outer edges on the right be somewhat crumpled and turned up; they will represent the stratigraphic exposition of eastern Colorado. Imagine the Sangre de Cristo to be the right arm of the titanic book reader, with his wrist and hand resting on the breast of New Mexico from the top of the sternum to the xyphoid cartilage. The Raton mountains represent an enlarged inner condyle of the radius; the Cimarron mountains will represent the thumb; the Mora spur the forefinger, and the tripartite main range the remaining digits. East of these latter is Las Vegas, west is Santa Fe, and the A. T. & S. F. railroad skirts the finger tips to reach the Rio Grande valley. Fancy these enormous fingers of a titan thrust into the leaves of another volume, upturning their leaves, tearing, crushing and crumpling them; the torn and jagged edges will in part typify New Mexican sedimentary strata.

In a general way the granitic mountains of the territory are ranged in north and south lines. A series of short ranges begins just a little southwest of the Sangre de Cristo and extends on the east side of the Rio Grande into Texas, and, crossing the river, continues into Mexico. The crests of its interrupted segments are from 8000 to 10,600 feet above sea-level. The ranges have but little breadth, but overlap each other in places, and their linear directions often differ by considerable angles. One flank of each mountain is an escarpment and the other strata blanketed. The average distance of this line of short ranges from the Rio Grande is about thirty miles. On the other side of the valley, at a distance averaging seventy-five miles from the stream, is the drainage axis of the continent, the "continental divide," so called. This is not a mountain range, in its northern part, but a tract of high mesas of stratified rock, Cretaceous. Granite hills protrude in places, giving evidence that at the base the axis is of that nature. Further south, and crossing the line of the Santa Fe railroad, western division,

the divide is capped with lava sheets. Still further south the granite base rises into a mountain range, the Black range. Mountains on either side of the divide rise to altitudes above the divide, but streams have cut canyons through them or have passed around their extremities. Detached ranges not far from the Rio Grande rise to heights of 8000 to nearly 11,000 thousand feet. The Ladrone, Magdalena and Caballo are the principal. But there are three groups or clusters of ranges prominent in situation, magnitude, general elevation and mining importance, namely, the Sangre de Cristo, or Red mountains (from the red feldspar of the granite), in the north-central part, the Black mountains in the southwest (from the black clothing of pine forests), and the White mountains in the southeast. They form a right-angled triangle, of which the hypotenuse is the line from the Sangre de Cristo to the Black mountains.

New Mexican orology well illustrates the principle that, in crust-wrinkling, horizontal thrust is from all directions and not from one or two, as in the action of a vise. However, the lines of weakness may not run in all directions; but it appears that, in New Mexico, the strata were too evenly laid to allow any great differential of resistance. Perhaps the absence of those enormously thick and rigid barriers to compression, the Cambrian, Silurian and Devonian rocks, may have had an influence in directing a distribution of effects to various points of the compass.

Mountain evolution did not cease in New Mexico until late Tertiary, if it has yet ceased. Extensive local faulting, totaling, in cases, 1000 feet or more, accompanied or followed elevation. This movement is still probably progressing, as is indicated by frequent slight earthquakes, local in perceptible effects. About the center of the territory a good number of seismic agitations occurred the present year (1904). Whether dislocation progresses by elevation of mountain masses, and corresponding slipping of strata in contact about the bases, or by extension of old faults further removed, is a question the solution of which may come by observing if changes of position occur in mining tunnels intersecting faults. Some suppose the faults increase without elevation, which is not probable unless a reason can be given for cavernous conditions. From the traditions of the Pueblo Indians and descendants of the early Spanish settlers, and from the evidences of former successful agriculture and large population where neither of these conditions exist to-day, the inference has been drawn that there is a general subsidence of the plateaus, but such data do not seem to warrant the conclusion. It is true that certain altitudes are necessary to cause aqueous precipitation, but these altitudes are not the same in all sections. Some high mountains secure very little;

others not so high get good supplies. Breadth of ranges seems to figure a good deal in the rainfall.

New Mexico is dotted and overspread with later intrusions than her granitic wrinkles, and of a different character. Basaltic cones and lava-beds intermingle in all parts of the territory, west of the Llano Estacado, with her mountain ranges and her park-like plateaus. Rhyolite often caps the summits of the higher peaks; but they were not the higher peaks when the molten rock was spread over them. Subsequent erosion has left them to tower above the crumbling granite masses by which they are surrounded, and which once looked down upon the sites now occupied by the cold vomit of Pluto. Young isolated cones of basalt rival in altitude the porphyritic monarchs of many geological ages. A line of these in a southwest direction begins near Colorado, between the Sangre de Cristo range and the Rio Grande river, and extends 200 miles. Among these peaks, Ute, San Antonio, Abiquiu, Hemas and Mt. Taylor are between 10,000 and 12,000 feet high. Mt. Capulin, in the northeast quarter of the territory, a noted landmark, 8000 feet high, has a crater a mile in diameter. Ten miles west of Albuquerque are five cinder cones, from 6000 to 8000 feet above sea, in a line, and visible from the city. The central one has an open crater and a secondary cone. Some of the basalts are vesicular or amygdaloid, and some massive and dark-purple basalt weathers to a white kaolin. Some rhyolites are pumiceous and some glassy and massive. Of course there are other varieties. The lava overflows are extensively spread on the plains or parks. A region of lava overflow, 300 miles in length and averaging twenty miles in width, in the midst of which the plutonic peaks above named and many others lift their heads above the desolation they have wrought, runs through northwestern New Mexico. In its northern part it is basaltic, and lies on both sides of the Rio Grande, which cuts through it in long, black chasms, in places 800 feet deep. It leaves the eastern side of the river about the parallel of Santa Fe, but, on the western side, is still a visible object from the city of Albuquerque, presenting the appearance of a perpendicular, high, black wall. A bed of black obsidian covers about 300 square miles a little southeast of the territorial center. It is known as the Malpais. Many sheets with local names might be mentioned in other sections of the territory.

As might be inferred, dikes and sills are numerous, and have effected important economic conditions, among which is the conversion of bituminous coal into anthracite, and the introduction of some metallic ores of profitable mining value. It is, however, a question whether the extrusive and intrusive plutonics have made New Mexico more fitted than it would otherwise have been for the production of

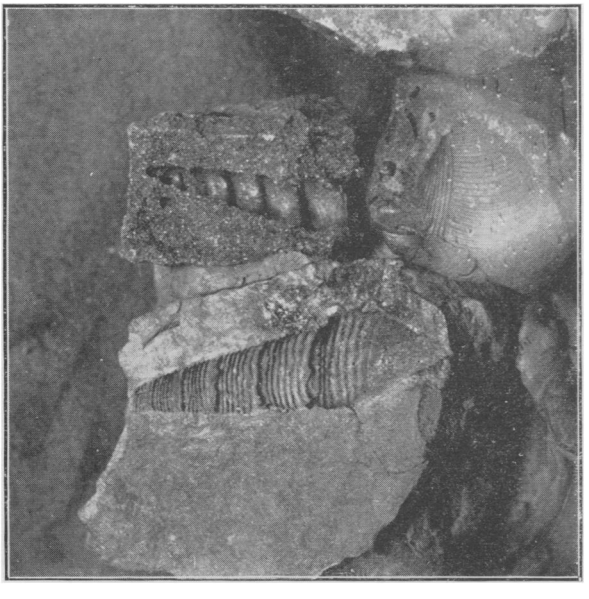

PLATE XV.—Mentor Fossils—*Turritella belvederei* Cragin.

wealth and for permanent civilized, prosperous and increasing population. They have restricted the formation of wide alluvial valleys and covered large areas of possible agricultural surfaces, converting them into sterile deserts. By damming the Rio Grande in late Tertiary times, it made the valley of that stream a great longitudinal lake or a series of linear lakes for several hundred miles of its course, which became filled with the detritus of basaltic and granitic masses to the depth of nearly 1000 feet. Thick layers of basalt run into its bed and spread on both sides of it, the stream finally cutting deep canyons to deliver itself. Much of the drift and sediments yet remain, as well as most of the broad, barren lava tables. The remains of the old lake deposit are seen to be stratified and sometimes feebly consolidated with calcium carbonate. The layers consist of silicious sand alternating with fine to very coarse conglomerate. The water-worn pebbles of the latter are often six to eight inches in diameter. Every description of color and composition of plutonics is found in the smooth stones that cover the mammillary faces of the low hills bordering the lower levels of the valley. One may sometimes find gold, which the naked eye can detect in the specimens he gathers, and many are colored by ores of copper or other metals. The cutting of the Rio Grande canyons resulted in several debacles, according to the evidence of distinct benches along the boundaries of the lake basin, especially marked in Colorado, but also manifest in New Mexico.

The granite of the mountains is mainly a feldspar porphyry, with the feldspar ingredient in rather large crystals. In the Sangre de Cristo this component is reddish, also in the Nacimiento and some other ranges, but further south it is oftener a white orthoclase. The granite passes into gneiss or *vice versa* in places, and where schists are in contact it is often that the junction is not a *locus* that can be identified. Quartz and granite dikes are frequently found cutting into the great axial masses. About fifty-five miles straight north of Santa Fe, near the Denver & Rio Grande railroad, is a granite dike carrying reddish feldspar in masses of four to five cubic feet, quartz masses as large or larger, and white mica plates several inches thick. The probability is that this dike was not thrust up to the surface, but cooled very slowly under great pressure, and is exposed through denudation by erosion of thick strata.

The gneisses, schists and granites show more or less lamination in the vertical direction, and some schists under the lens exhibit clastic structures. Apparently they do not conform with the layers of conglomerate and quartzites that rest upon them on the sloping flanks of the ranges, when viewed from the escarpment faces. They are below the Carboniferous and are supposed to be Algonkian metamor-

phics. No remains of Cambrian, Silurian or Devonian strata are recognized. If any of these systems were ever deposited, they appear to have been completely removed, unless the metamorphics are remnants. The upper surfaces of these Azoic masses are scored into bosses and fosses, and the latter are filled with conglomerates and quartzites on which limestones of the Carboniferous period lie conformably, the first clearly defined Paleozoic strata in the territory. The whole series of the Carboniferous, except coal seams, is displayed,

New Mexico appears to have been immersed in the sea when the ferns and club-mosses of eastern Kansas formed dense cryptogamic forests, for millions of years, flourishing upon hundreds of feet of the dead bodies of their species. Most of the mountains have carried upon their summits extensive and thick beds of Carboniferous limestone, sometimes in nearly horizontal attitudes. On the summit of the Sandia range, opposite Albuquerque, at an altitude of 10,000 feet, are two vast tables of Carboniferous limestone several hundred feet thick, lying one above the other and separated by a bed of sandstone. Viewed from the city these beds appear horizontal, but in reality they have a small dip to the east. They extend miles along the crest, and their conspicuous light-colored and uniform borders present a strong contrast to the darker, serried, granite pyramids that stud the steep slope below. They attract the attention of the traveler as a remarkable sight. No better illustration can be had of the slow, non-impulsive elevation of granite ranges than the attitude of these extensive tables 5000 feet above the base of their upheaved support. The writer has seen masses of the debris of these strata composed almost wholly of small brachiopod shells loosely cemented by calcium carbonate. Near to and opposite the escarpment sides of the mountains the Carboniferous and other strata are usually canted up at high angles.

The Triassic and Jurassic are extensively displayed in northern New Mexico, and probably in the southern part, west of the Pecos valley, in all their colors. In various places the Jurassic is capped with gysum fifty feet or more in thickness, which would represent more than 25,000 feet of sea-water evaporated. The southern part of the Gallinas and northern part of the Nacimiento mountains, about eighty miles northwest of Santa Fe, have their summits covered for many miles with gypsum, above Jurassic sandstones and shales, at a height of 10,000 feet. Gypsum is found in various connections, but most often with the Jurassic. West of the Sacramento mountains, in the southeastern part of the territory, is an area of 600 miles covered with gypsum sands heaped into white dunes by the wind. It is dangerous to attempt a penetration of this dazzling desert. In places

gypsum beds are found upturned at an angle of 90 degrees. The Trias and Jura beds do not fall short of 1000 feet, or one-half that of the Carboniferous, in thickness.

The system most frequently exposed is the Cretaceous. All the formations from the Dakota to the Laramie are represented. There is much of interest in connection with each, but space in this paper does not allow details of those below the last named. It is the Laramie that is the most interesting, and that has the greatest economic value. Its thickness is one-third that of the entire Cretaceous. It is also widely developed. It seems to be wholly a fresh-water deposit, lacustrine or estuarine, and paludine. Its beds are sandstone, shale or clay, and coal, with later intervening plutonic intrusives. The Laramie period was a long one, and its climate was temperate. The scarcity of limestone precludes deep seas; the absence of gypsum indicates that no wide marine, littoral basins were overflowed by the tides, and their waters left to be evaporated by the sun. But the flora is sufficient evidence of the character of the aqueous depository. Little of sulfur or iron is found, which argues a period of plutonic inactivity and a drainage area devoid of extensive volcanic products. A series of great lakes, probably, extended from Mexico, or perhaps the City of Mexico, to southern Alaska, perhaps the longest chain of lakes in geological history. Their outflow was probably into the Pacific, principally through the Columbia and Colorado rivers. The area of erosion was largely one of granitic and metamorphic rocks, with much quartzite. Under continued deposits, mostly silicious sands and fine clays, the lakes became fens, or their marshy margins were greatly broadened and became the habitat of dense coniferous forests, the origin of the Laramie coal-beds; a vegetation entirely different from that which produced the coal-beds of Kansas. Through progressive elevation, the outlets of the lakes were raised by degrees exceeding the erosive effects of the clear lake water, and the flat forest-covered lands about the lakes became overflowed, and the forests were drowned out. The sand and silt which had heretofore been carried into the lakes through drainage channels now began to be dropped in the overflowed flats; more of them than heretofore were carried through the outlets, scouring these more rapidly.

The sandy flats were once again but moist or swampy grounds. Between raising the surface of the lowlands by sediment, and deepening the lake outlets by increased corrading material, the equilibrium was restored and passed. Perhaps pauses in the elevating forces may also have aided the effects. Resinous, rank conifers once more occupied the drained surfaces and the material for coal-beds accumulated. Alternately the conditions described succeeded each other, until scores

of thick or thin coal-beds were laid, with intervening layers of sandstone and shale. As sea saurians and marine mollusks have been found in supposed Laramie, it is probable that at times the outlets may have been so lowered as to admit the influx of tides or currents, producing brackish conditions, but the exclusive fresh-water view is intended to apply only to New Mexico. In the disintegration of granitic rock, the feldspar and mica and other basic constituents yield and are washed away before the quartz is reduced to sand; hence the shale in the Laramie is generally overlaid by sandstone, and the coal-beds have mostly a sandstone roof. This enables them to be operated with greater security and less labor and expense than in many other coal-fields.

The workable coal-seams vary in thickness from three and one-half to forty feet; where the latter extreme is found want of transportation facilities renders the seam unavailable. It lies in the northwest part of the territory, between the western division of the Atchison, Topeka & Santa Fe railroad on the south and the Denver & Rio Grande railroad on the north. The field embraces more than a million acres, and is 125 miles in length. The southern exposure of this coal-field is exploited about Gallup, near Arizona territory. The coal is a lignite, in two series of seams, with 400 feet of rock between them; but it borders on the bituminous, and is sometimes strictly of that grade. In these coals resinous gum is found distributed in small masses about the size of a pea. It crumbles easily and is difficult to collect. It was first discovered in 1873, and was then new to science, and was given the name "wheelerite," in honor of Lieut. George M. Wheeler, engineer in charge of the exploring expedition. From these mines are also obtained sections of trunks or limbs of exogenous trees, with the concentric rings plainly visible. One of these sections is in the rooms of the chamber of commerce at Los Angeles, Cal.

The Coal Measures in the region of Santa Fe are much broken by intrusive dikes and sills of porphyritic lava; so, also, in the northeast and in the southeast parts of the territory. The interesting consequence is the change of whole seams, or only portions, from bituminous to anthracite, or to semi-anthracite; the best anthracite being equal in quality to the Pennsylvania product. In one instance, near Cerrillos, a plutonic sheet, 350 feet deep, lifted the upper end of an inclined coal-bed and its floor of sandstone and floated them over another part of the same, metamorphosing both the transported and the *in situ* portions. Coal is found on the tops of some mountains in small patches, whether of Laramie age is doubtful, but Laramie coal is found in each of the four quarters of the territory, which seem to have been wooded, then as now, with

large areas of coniferous trees; but, very differently from the present, they were also spotted with extensive swamps for conserving the dead generations of their arborescent giants, or it may be pigmies.

Eocene deposits are found both east and west of the Sangre de Cristo, and probably exist in other parts of the territory. West and north of the Gallinas mountains is a *mauvais terres*, rivaling in aspect the similar region of Wyoming, Dakota, and Nebraska. Silicified tree trunks, some several feet in diameter, are abundant. Many reptile and some mammal remains have been removed from its marl beds The marl beds are bordered by sandstone of the same age and interstratified with it. This region was the site of a large fresh-water lake in Eocene times, and its sediments aggregate 1000 feet in thickness. The marl when wet becomes very slimy, and the wash from it adds greatly to the turbidity of the Rio Grande waters.

The Middle and Late Tertiary are represented in the Rio Grande valley extensively. It was during this period that it was the bed of a lake, or a series of linear lakes, extending for hundreds of miles, and probably due to lava flows. The Llano Estacado upper strata are considered of this age for 100 feet in depth, perhaps more. The remains of an immense dog, as large as a bear, the three-toed horse, the mastodon, the rhinoceros and the camel have been taken from the marls.

During the Glacial period New Mexico doubtless received cataclysmic rains with great frequency, and her canyons and mountain slopes were deeply eroded by rock fragments, carried with torrential force against granitic and basaltic ramparts, while Pluto and Vulcan joined forces to flood with fiery streams her watercourses and to plaster some of her valleys and park like plateaus with a coat of nether-world cement. It was probably in this age that the Rio Grande freed its channel from the natural bars of the Pliocene eruptions.

In conclusion, it may be said the succession of formations in New Mexico and Kansas are not very different, except as regards the Coal Measures, but the physical features of surface are widely in contrast.